

Life cycle thinking in graduate education: an experience from Brazil

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Abstract

Purpose This study presents an educational experience, of a Brazilian center of technological education, focused on the involvement of undergraduate and graduate students, according to directions of UNEP/SETAC Life Cycle Initiative. It describes an institutional collaborative work, aligned with the Life Cycle Initiative, and evaluates the main actions implemented through a set of indicators, which show the organizational dynamics and changes in the professional profiles of students, between 2006 and 2012.

Methods The description of the institutional collaborative work was based on direct observations conducted by the authors, who participated in the experience, and on a documentary research involving data from academic system. This

effort led to representations of (a) key interactions among actors of organizations and (b) a set of 11 indicators of changes for individuals and organizations. Interviews with students and representatives of organizations also contributed to generate the structure of the network and to fulfill the set of indicators.

Results and discussion Among the research findings, two were considered more relevant from the direct observation: (a) the structuring of an effective laboratory supported by public funds to conduct the educational experience and (b) the introduction of life cycle thinking (LCT), life cycle management (LCM), and the methodology of life cycle assessment (LCA) as optional areas of study for students. The offer of regular classes, supported by software, and the organization of small-scale research projects made the work feasible, altogether, improving the interest and cooperation of different graduate and undergraduate student groups. This outcome increased the interactions with other public and private organizations; much additional research was accomplished.

Conclusions The experience contributed to materialize the LCT, LCM, and LCA themes and persuades the actors to reflect on new reflections concerning the necessity of changes in their professional profiles. This suggests a potential to produce organizational improvements and innovations. However, some challenges must be faced in Brazil: organization of the national inventory, improvement of academic knowledge and more engagement of scholars, as well as the lack of guidance and assistance to consolidate local and national collaborative work.

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1 Introduction

In spite of the increased awareness concerning the importance of sustainability, the incorporation of this concept in the practices of organizations is still a challenge (Scoones et al. 2007; UNEP/SETAC 2012). To face this challenge, the Life Cycle Initiative, a joint organization between the United Nations Environmental Program (UNEP) and Society of Environmental Toxicology and Chemistry (SETAC), has undertaken efforts to foster the life cycle thinking (LCT). LCT consists in “going beyond the traditional focus and production site and manufacturing processes to include environmental, social, and economic impacts of a product over its entire life cycle”. It is an approach that aims “to reduce a product’s resource use and emissions to the environment as well as to improve its socio-economic performance (...) within an organization and through its entire value chain” (UNEP/SETAC Life Cycle Initiative 2013). Therefore, LCT would be a way to transform people, processes, and organizations worldwide (UNEP/SETAC 2012).

LCT is supported by the life cycle management (LCM) and the life cycle assessment (LCA) techniques. LCM is a reference to performance analysis and management that can be adopted by companies, focused on sustainability, to produce goods and services with minimized environmental impacts (UNEP/SETAC 2009). In turn, as defined in the ISO 14040: 2006, LCA is a compilation and evaluation of inputs and outputs of a production system throughout its life cycle, as well as the potential environmental impacts (ISO 2006). In the last decade, national and transnational laws, public financing rules, and other governance elements have progressively incorporated the obligation to execute LCA as a requirement for production, distribution, and selling of products and services (UNEP/SETAC 2012; MDIC 2010; Brasil 2011). The second decade of the twenty-first century will be the decade of sustainability in which LCA will address key questions about product diversity, sectors, and mechanisms (Guinée et al. 2011).

The development of the LCT must be based on networking (Schebek 2012), which demands partners, funding, time, and a construction of a common ideology, communication, direction, and guidance. As this is an interdisciplinary field, the process of socialization among the various actors of the network is necessary for sharing and converging of concepts, experiences, approaches, and methods from different research areas (Kuhn 1962; Schebek 2012). In this conception, networking, involving the production of knowledge, new visions and educational practices, and new forms of social interaction stand out as the foundation of an environment of creativeness and innovation (Wierzbicki and Nakamori 2005) addressed to practices.

Networking oriented to LCT can be observed through a multiplicity of efforts to produce knowledge, as demonstrated

by de Souza and Barbastefano (2011) and Swan et al. (1999). Other efforts are oriented to achieve interdisciplinary technological development in general (Mulvihill et al. 2011; Pahl-Wostl et al. 2013), which have the potential to converge with LCT, and there are also many actions to promote education for sustainable development (Paletta and Vieira Junior 2008; Wals 2009; Hall and Howe 2010). It is important to consider that, in the basis of such huge social transformation, education has a key role (Leach et al. 2012) to improve creativity, as it is capable of changing the awareness and attitudes of people (Manitoba 2000; Wade and Parker 2008). For Agenda 21, educational projects and initiatives are permanent targets in any scenario (United Nations 2012). This is an open space for research and innovation, and there are multiple initiatives worldwide (Hesketh et al. 2006; Huggins et al. 2008; Aurandt and Butler 2011; Powers et al. 2011; Perdan et al. 2000). Therefore, the fundamental thought is that all this development toward sustainability cannot happen without the essential contribution of education.

Within this scope, the present study aims to analyze an experience to the introduction of topics related to LCT, as LCA and LCM, into the education of graduate and undergraduate students of the Brazilian public institution of higher education, CEFET/RJ (Federal Center for Technological Education Celso Suckow da Fonseca). This analysis includes a description of the experience that started with a reception of a software license UMBERTO™ following an international LCA Award Program led by UNEP/SETAC Life Cycle Initiative, focusing on the study of LCA in 2006 (Baumann 2000); the representation of a collaborative network formed around this experience; and (Brasil 2011) indicators proposed to evaluate changes in the individual and in the organizational context of the professional performance of students through the dissemination of acquired knowledge. Changes in the organizations involved are examined as potential elements to innovation oriented to sustainability (Stirling et al. 2007; Leach et al. 2007) accordingly with expectations of the initiative.

2 Methods

This study was based on an academic experience occurred at a nearly 100-year-old Brazilian public institution of technological education that included teaching and research related to LCT, LCM, and LCA topics.

Its development was based on (1) direct observation conducted by the authors who participated in this academic experience; (2) a survey of documents in the academic system, such as those related to students and disciplines, undergraduate research projects, undergraduate final projects, master’s degree dissertations, doctoral thesis, and an analysis of the covenants with other institutions and research projects funded

by official funding agencies; and (3) interviews with students and representatives of the involved organizations, which took part in this educational experience. These actions were developed in order to identify signs of change in the students and in their workplaces, thanks to the assimilation of the concepts related to LCT and the learning of tools such as LCA and LCM.

First, it was introduced as a brief description of the experience, with the identification of the main actors and actions performed, which led to a collaborative network, where 157 people and 26 institutions are directly represented. Among them, 25 students were selected to be monitored, as they developed their research projects (resulting in doctoral thesis, master's degree dissertations, undergraduate research projects, or undergraduate final projects). The information about this group informs Table 1.

Some events of the collaborative work were arranged in a timeline (Fig. 1) starting in 2006, with the introduction of the free software license UMBERTO™, received during the implementation of an international cooperation project between Brazil and Germany—PROBAL until 2012. Next, the net of collaboration was represented, and the relationships between the various human and institutional actors were highlighted (Fig. 2).

Subsequently, a set of 11 logical and numerical indicators was developed to identify the changes, both in individuals and in the dynamics of the organizations where students were enrolled. These indicators were built with information coming from (1) direct observations conducted by the authors as participative researchers, (2) survey of documents, and (3) interviews with the students and representatives of organizations. The key questions and the numerical values used in these interviews to build the indicators are presented in Table 2.

Finally, the last step was to analyze the network dynamics and discuss patterns and particular issues relevant to guide any future initiatives inside this network or potentially interesting to implement or improve similar projects in other social segments. This is accomplished with the data summarized in Table 3 and a set of radar graphics used to do cross-analyses of actors' characteristics and the changes observed.

3 Results and discussion

3.1 Brief description of the experience

The first contacts with LCA-related topics began with an exchange program between Brazil and Germany (PROBAL) when CEFET/RJ took part of a project developed in partnership with UFRJ (Federal University of Rio de Janeiro) and the Technical University of Darmstadt (TU-Darmstadt), Germany funded by CAPES (2013) and DAAD (German Academic Exchange Service). In the same period, there was a seminar in Brazil organized by CEFET/MG (Federal Center of Technological Education of Minas Gerais)—The Role of Life Cycle

Assessment in Industry Involvement with Sustainable Development (CEFET-MG 2012)—in order to develop a net of multipliers for dissemination of LCT. In this event, there was a presentation of LCA and its applications with utilization of UMBERTO™ and SIMAPRO™. It was within this program with TU-Darmstadt and UFRJ that CEFET/RJ was given a free license of UMBERTO™ (from the LCA International Award) and then used it the following year for issues related to LCT in research activities and in the training of undergraduate and graduate students at the institution. UMBERTO™ was installed in the Laboratory for Research and Development of Models (LPDMO). LPDMO is equipped with computing resources and is used to support teachers, graduate students, and undergraduate students involved in research activities, allowing interaction among different levels of education.

A class of LCA was created for graduated students of the Masters Course of Technology of CEFET/RJ, and it has been offered annually since then. This course, despite being inserted in the production engineering area, is sought by professionals coming from different areas of knowledge. These professionals find a post-graduation course with an interdisciplinary approach. Another LCA class was offered to undergraduate students of production engineering, as an elective class, aiming to increase interaction between educational levels. Another target was to stimulate the interest of engineering students to continue their academic training and pursue a master's degree. These LCA courses had comprehensive pedagogical projects looking to discuss the concepts of LCT and LCM and, in this context, to offer a theoretical and practical approach of LCA including training with software and the study of practical cases.

During this experience, the graduate students began to act as mentors for undergraduate students and produced courseware to support the new discipline offered in the production engineering curriculum. Some research projects involving LCT, LCM, and LCA were developed, parallel to teaching activities, in the following categories: (1) undergraduate research project for engineering students, (2) final course project for undergraduate students, (3) master's degree dissertation, (4) doctoral thesis, and (5) projects funded by official agencies. The following approval of two projects funded by official funding agencies (FAPERJ—Research Support Foundation of the State of Rio de Janeiro, CAPES) allowed the expansion and improvement of the research infrastructure in the institution.

- The first project funded by FAPERJ had the objective to improve local engineering development, and it demanded the partnership with a private company that required co-operation and co-funding. The ECOWOOD, a company that produces plastic wood, became this partner.
- The scope of the second project was to disseminate technological and scientific knowledge in Rio de Janeiro. It was used to organize a collaborative net to create a local

Table 1 Characterization of the students who have developed research projects related to LCT, LCM, and LCA

Category	Origin	Research theme	Funding	Year i	Year f	Related organization	Nature/type	Bond
MS	IT	LCA: Plastic Bags Production	CAPES	2006	2007	PLASTIC BAGS IND	Enterprise	Covenant
MS	MAN	LCT: Solid Wastes Manag.	CAPES	2006	2008	TIRE DEALER NET	Enterprise	None
MS	ENGPRO	LCT: Solid Wastes Manag.	CNPq	2006	2008	AUTO MAINT	Enterprise	None
MS	MAN	LCA, LCM: Plastic Wood Production	CAPES/ FAPERJ	2007	2009	PLASTICWOOD IND	Enterprise	Covenant
MS	PHAR	LCM: Supply Chain Governance	CAPES	2008	2009	PHARM IND P.ORG. 1	Enterprise	Covenant
MS	PHAR	LCA, LCM: Pharmacy Education	CAPES	2008	2010	PHARM IND P.ORG. 2	University	Covenant
MS	ECON	LCA, LCM: Bread Production	None	2008	2010	BREAD IND	Enterprise	Employee
MS	ENGEL	LCA, LCT: Basic Education	None	2008	2010	EDU ORG 1	University	Covenant
MS	ENGCH	LCT: ORG STUD Money Press	None	2008	2010	PUBLIC ENTERP 1	Enterprise	Employee
MS	ENGEL	LCA, LCM: Eletronic Wast Manag.	CAPES	2008	2010	CEFET-RJ EDU ORG BR	University	Student
MS	ENGMEC	LCT: ORG STUD, Tire Production	None	2008	2010	TIRE IND	Enterprise	Employee
MS	ENGPRO	LCA, LCM: Animal for Experiment	None	2008	2010	HEALTH RESEARCH P. ORG.	Research inst	Employee
SI	ENGST	LCA: Plastic Wood Production	CEFET	2008	2009	PLASTICWOOD IND	Enterprise	Covenant
SI	ENGST	LCA: Plastic Wood Production	CEFET	2008	2009	PLASTICWOOD IND	Enterprise	Covenant
FP	ENGST	LCT: ORG STUD, Off. Ind. Funding	None	2009	2009	PUBLIC ENTERP 2	Enterprise	Employee
MS	ENGELE	LCA, LCM: Film Production	CAPES	2009	2011	ENTERTAINMENT	Enterprise	Covenant
MS	PHAR	LCA: Antiophidic serum	CNPq	2009	2011	PHARM IND P.ORG. 3	Institute	Covenant
MS	MAN	LCA, LCM: Building. Mainten.	None	2009	2011	EDU ORG 3	University	Employee
MS	MAN	LCT: 21 Agenda. Social Net B.P.	None	2009	2011	EDU ORG 2	Institute	Covenant
SI	ENGST	LCA: Plastic Wood Production	FAPERJ	2009	2010	PLASTICWOOD IND	Enterprise	Covenant
SI	MANST	LCA: Tire Reverse Logistic	CEFET	2009	2010	PLASTIC IND	Enterprise	Covenant
SI	ENGST	LCA: Plastic Wood Production	FAPERJ	2009	2010	PLASTICWOOD IND	Enterprise	Covenant
DS	NUTRI	LCA, LCM: Fisch for Collective Food	CNPq	2010	2012	COLLECTIVE FOOD SERVICE	Enterprise	Covenant
MS	PHAR	LCA: Antiophidic serum	CNPq	2010	2012	PHARM IND P.ORG. 3	Research inst	Covenant
FP	ENGST	LCA: Pump Manufacturing	None	2011	2012	FUEL PUMP IND	Enterprise	Covenant

SI scientific initiation (undergraduate student), *MS* master student, *DS* doctorate student, *FP* final project (undergraduate student), *ECON* economy, *ENGMEC* mechanical engineering, *ENGELE* electronical engineering, *ENGEL* electrical engineering, *ENGPRO* production engineering, *ENGCH* chemical engineering, *IT* information technology, *MAN* management, *NUTRI* nutrition, *PHAR* pharmacy, *B.P.* blind people

Agenda 21 (United Nations 2012) with a group of blind people. These students with special needs came from another public educational organization and attended courses, thanks to distance learning technology, specially conceived for them.

The budget for the two projects was approximately US\$120,000.00, and there were economical counterparts from CEFET/RJ and ECOWOOD. These resources made it feasible to improve the LPDMO laboratory to produce didactical materials for students in general and, specially, for the blind and students with disabilities. New students came to the courses, and this has diversified the activities. In 2010, an external doctoral student joined the network, and one of the professors of CEFET/RJ acted as co-supervisor. New software licenses were bought, and several students were trained to use

them. The teaching and research activities generated in turn, a growing connection with several other institutions forming a network of scientific collaboration around the themes of LCT, LCM, and LCA.

In this context, partnerships with universities, research institutes, non-profit organizations, and public and private companies operating in various economic sectors were established. The relationship with other universities covered national and international partnerships. In the former case, relationships involved the training of graduate students from other institutions on LCA, co-supervision of master's degree dissertations, and doctoral thesis, as well as joint development of research projects. In the latter case, the relationships involved teachers from universities in Germany and Portugal. In Germany, a collaborative relationship was organized around research projects funded by CAPES and DAAD agencies. In

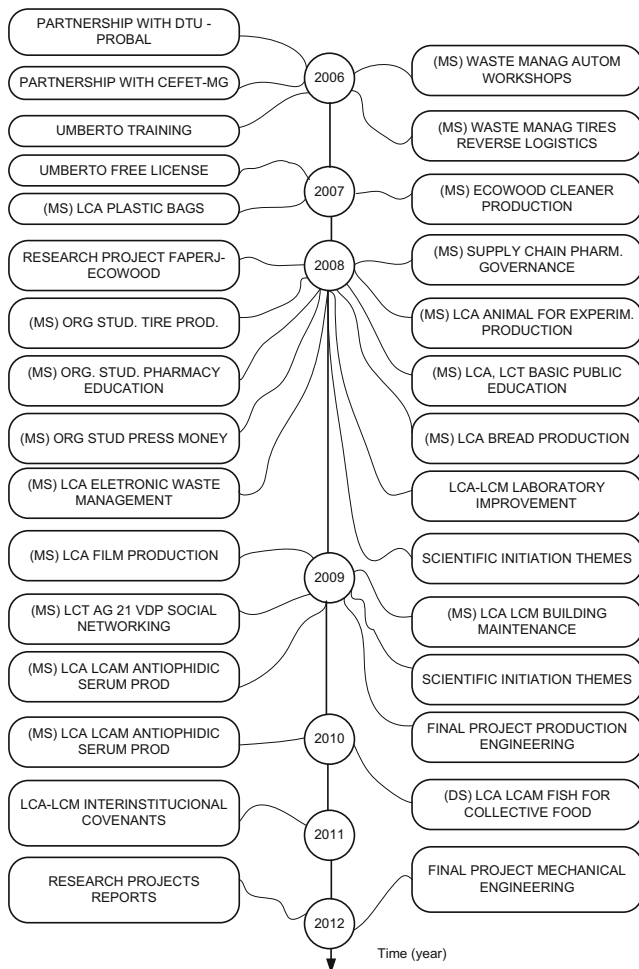


Fig. 1 Timeline of events involving individuals and organizations

the case of Portugal, one of the teachers from CEFET/RJ did a post-doctoral internship at the University of Coimbra, creating a partnership that has remained until the present time. The other institutions became the settings for the development of empirical researches conducted by undergraduate and graduate students.

3.2 Training of the collaborative network

This section presents a description of the actors, who took part in this educational experience, their relationships and the evolution of events that led to the formation of the network.

3.2.1 Description of the actors

The group of people who integrate the network is divided as follows: 132 undergraduate students, 125 students that registered for the LCA class, 2 students from the Engineering Final Project Course (FP), and 5 undergraduate students in Scientific Initiation (SI); 17 master's degree students (MS) from CEFET/RJ; 1 doctorate degree student (DS) from another

university (UFRRJ—Rural Federal University of Rio de Janeiro); 3 professors from CEFET/RJ; 4 professors from other universities from Brazil (UFRJ; UFRRJ; UFF - Fluminense Federal University; CEFET/MG); 2 foreign professors and 1 Brazilian professor from universities in other countries (1 from Portugal and 2 from Germany); and many others professionals from the staff of the organizations where the research projects were developed, which are not accounted in this model.

The institutional actors taking part in the network are the following: 3 funding agencies (FAPERJ; CNPq—National Council for Scientific and Technological Development; CAPES—Coordination for the Improvement of Higher Education Personnel); 15 public organizations: 6 Brazilian universities, 2 foreign universities, 2 research institutes, and 3 public enterprises; 2 educational organizations; and 10 private enterprises belonging to different economic sectors.

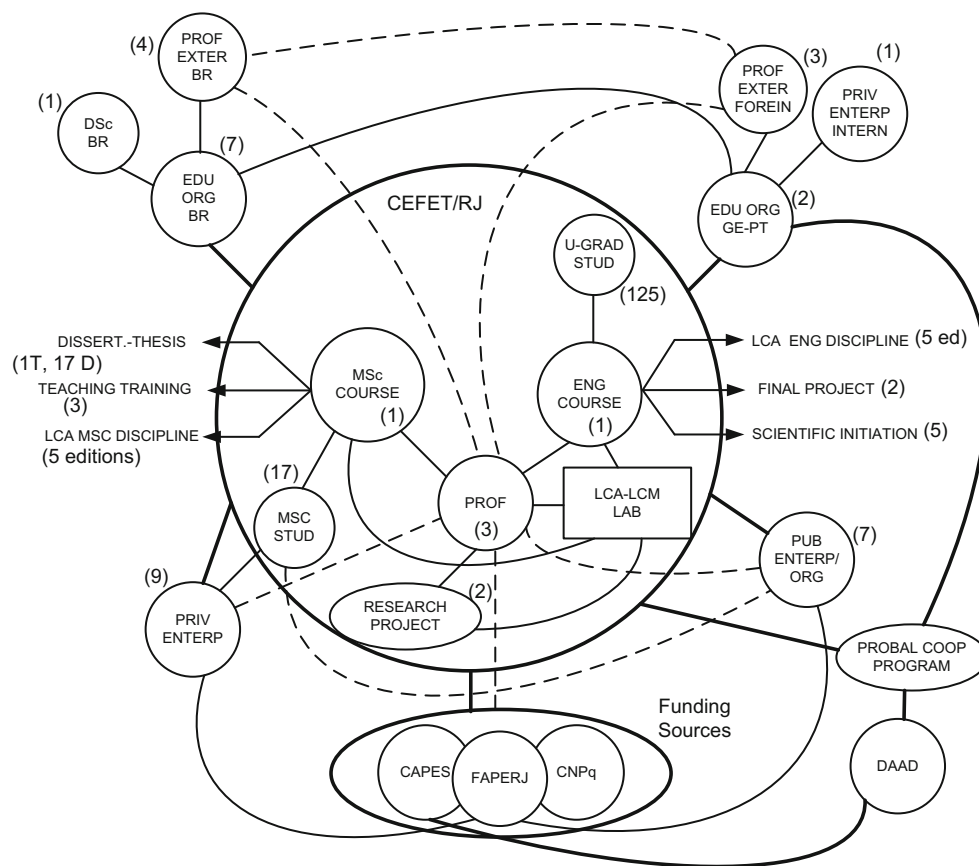
These actors were identified and catalogued through categories of attributes, aiming to construct a systematic representation of their relations. Because of its educational nature, the focus of the present analysis are the 25 students who, over the period 2006–2012, concluded research projects related to LCT, LCM, and LCA. The other 125 undergraduate students, who were only registered in the LCA class, were not accounted in this analysis because they were not yet in touch with the other organizations considered (as they were mostly students of earlier semesters).

The research projects, developed by the students, were categorized as doctoral thesis (DS), master's degree dissertations (MS), final project (FP), and scientific initiation (SI). The first two categories (DS and MS) were performed by graduate students and the last two (FP and SI) by undergraduate students.

Table 1 presents the characteristics of these students showing: type of research project conducted; origin corresponding to undergraduate degree or current graduate course; the subject of the research project, whether the project had some sort of financing (funding agency indicated); year of initiation (year i) and completion (year f) of the research project developed; the sector of the organization in which the project was developed; the type and nature of the institution; and whether the student had a professional bond with the institution.

In Table 1, only the students are related along the timeline in the first column (left). The diversity of academic graduations of origin can be also observed. In the case of master's students, it has to do with the multidisciplinary nature of the course proposal, which is centered in production engineering and has lines of research compatible with other areas of knowledge. The undergraduate students are mostly from production engineering and a few from management and mechanical engineering. They were involved with scientific initiation or final project. This can be explained because the LCA class is offered, until now, only for production engineering

Fig. 2 Taxonomic representation of collaborative net. *Dashed lines* are personal bonds and *solid lines* are institutional bonds



students. In sum, engineering students, including its five specializations (chemistry, mechanics, electricity, electronics, and production), represent the largest part (13 in 25) of the whole group of graduated students. However, pharmacists and administrators are the greater single groups. There were some students who received research subvention from CEFET/RJ and, due to that, CEFET/RJ appeared as funding agency in these cases. In all other cases, CEFET/RJ took part in indirect funding of all activities, but this was omitted. The endurance of the relationships, in some cases, was longer than a period of 24 to 30 months; it usually lasted through the conclusion of the master's degree. LCT influenced all research themes and, the vast majority of them, used with LCA or LCM in direct applications related to sustainability. The organizations related to the students are listed to the right, as well as their nature and type. The last column indicates the type of bond between the student and the organization. The darker cells are private companies and the lighter are public ones. The size and the nature of the activities vary among the organizations. This detailed study is beyond the scope of this article, but it is interesting to comment that the tire industry and the industry that produces fuel pumps are large transnational entities, while the baking industry is one of the five most important companies of this sector in Brazil.

3.2.2 Timeline of events

A timeline, based on the report of the experience and the identification of actors, was drawn in Fig. 1. The year 2006 was taken as the initial mark in order to describe the history of major events of interest to this analysis. The larger number of events between 2008 and 2009 is related to several issues, including the variability in the number of incoming graduated students and availability of the professors to supervise master's degree dissertations.

3.2.3 Representation of the collaborative network

Figure 2 represents the structuring of the collaborative network involving the actors and the relationships previously described.

The intention of this model is taxonomic. Actors are specified by type and appear only once, while the number of actors of the same type is shown within brackets. The bigger ellipse is CEFET-RJ. A typical academic structure that lives inside this central institutional actor, students and professors, who are involved in some common courses share labs and participate in common research projects. Regular activities of graduate students are classes, master's degree dissertations, or thesis. There is also a

teaching training program with which they interact with undergraduate students under the supervision of a professor, as was the case of the mentoring of LCA classes for engineering. Undergraduate students attend classes and participate in scientific initiation or final project. The solid lines are formal relationships determined by job or covenant rules. The dashed lines are personal relationships like partnership or personal contracts, funding, and practicing periods in a company. Outside CEFET/RJ, there are other educational organizations. FAPERJ, CNPq, and CAPES are official funding agency and were grouped in an ellipse. FAPERJ belongs to a local state government and the last two belong to the federal government. DAAD is an agency of the German government for international academic exchange. There are also private and public enterprises, professors (external to CEFET/RJ but in Brazil and in Germany and foreign professors from Germany and Portugal). PROBAL is also highlighted, as an

international cooperation program between Brazil and Germany.

This description is “as built” because the social network was not previously planned. As the focus here was educational, the academic actors and relationships are highlighted, but one could think about it using the triple helix model (Lawton Smith and Leydesdorff 2012) since government, private, and public organizations and universities interacted at all times. It is important to highlight that the non-academic organizations, more than funding, contributed with the empirical space for researching (changes in organizational culture), and their productive processes became vital objects for LCA and LCM studies. This happened because either the master’s degree students were also employees in these companies or there were institutional bonds with CEFET/RJ, which opened important doors to access and discuss real-life data. In the present Brazilian context, this is the main, if not the only, field to work with LCA and LCM themes out of an academy.

Table 2 Structuring of the indicators of changes for individual organizations

Indicator	Description	Value/meaning
PPE: previous professional expertise	Do you have any previous expertise (professional experience or formal studies) of LCA before the course done?	0 No, I have none. 1 Yes, I have some
CPA: change in professional attitude	Was the knowledge of LCA, LCM, or LCT incorporated to conception or to operation routines in professional life?	0 No, there were no changes 1 Yes, I have changed myself
CAOP: change in academic or organizational profile	Were there changes in professional bonds? This could happen with changing professional activities done before or with migration to another job inside the same organization or yet with the migration to another organization.	0 No, there was no change 1 Yes, there were some changes
CPT: change in professional trajectory	Were there changes in professional trajectory and job bond of the graduated?	0 No, there was no change 1 Yes and I stayed in the job 2 Yes, and I found another job
MDLF: motivated discussion with local focus	Was there any discussion in local group and motivated by your direct action about sustainability and LCT, LAC, or LCM?	0 No, none relevant 1 Yes, there was
MDAF: motivated discussion amplified focus	Was the comprehensiveness of the discussion motivated by your actions amplified, reaching other segments horizontally or vertically?	0 No, it was not 1 Yes, it was
MSD: motivated strategic discussion	Did the discussion, motivated by your actions, reached the strategic level of the organization?	0 No, it did not 1 Yes, it did
MMC: motivated management change	Were there changes in the management of the processes in the local level motivated by your actions?	0 No, there were not 1 Yes, there were
MPC: motivated planning change	Was there any effect in the planning of the organization or in the decision-making processes in bigger areas of the organization motivated by your actions?	0 No, there was no change 1 Yes, there were some change
MSC: motivated strategic change	Was there any change that reached the highest management staff?	0 No, there was no change 1 Yes, there were some changes
MOC: motivated organization change	It was used to map the global level of changing reached by the organization and accumulated the values of the six previous indicators (=MSC+MPC+MMC+MSD+MDAF+MDLF)	0 No changes occurred 6 The highest level of changes occurred.

Table 3 Analyses of indicators of changes for individual organizations

Category	Origin	Research theme	PPE	CPA	CAOP	CPT	Related organization	Nature/type	Bond	MDLF	MDAF	MSD	MMC	MPC	MSC	MOC
DS	NUTRI	LCA, LCM: Fisch for Collective Food	0	1	0	2	COLLECTIVE FOOD SERVICE	Enterprise	Covenant	1	1	1	1	1	1	6
MS	MAN	LCA, LCM: Plastic Wood Production	0	1	1	2	PLASTICWOOD IND	Enterprise	Covenant	1	1	1	1	1	1	6
MS	PHAR	LCA, LCM: Pharmacy Education	0	1	1	2	PHARM IND PORG. 2	University	Covenant	1	1	1	1	1	1	6
MS	ECON	LCA, LCM: Bread Production	0	1	1	1	BREAD IND	Enterprise	Employee	1	1	1	1	1	1	6
MS	ENGEL	LCA, LCM: Film Production	0	1	1	2	ENTERTAINMENT	Enterprise	Covenant	1	1	1	1	1	1	6
MS	PHAR	LCA: Antiophidic serum	0	1	1	1	PHARM IND PORG. 3	Institute	Covenant	1	1	1	1	1	1	6
MS	PHAR	LCA: Antiophidic serum	0	1	1	1	PHARM IND PORG. 3	Research inst	Covenant	1	1	1	1	1	1	6
FP	ENGST	LCA: Pump Manufacturing	0	1	0	1	FUEL PUMP IND	Enterprise	Covenant	1	1	1	1	NA	NA	4
MS	ENGEL	LCA, LCT: Basic Education	0	1	1	2	EDU ORG 1	University	Covenant	1	1	1	1	0	0	4
MS	ENGCH	LCT: ORG STUD Money Press	0	1	0	0	PUBLIC ENTERP 1	Enterprise	Employee	1	1	1	1	0	0	4
MS	IT	LCA: Plastic Bags Production	0	1	1	0	PLASTIC BAGS IND	Enterprise	Covenant	1	1	1	0	0	0	3
MS	PHAR	LCM: Supply Chain Governance	0	1	1	2	PHARM IND PORG. 1	Enterprise	Covenant	1	1	1	0	0	0	3
MS	MAN	LCA, LCM: Building Mainten.	0	1	0	1	EDU ORG 3	University	Employee	1	1	1	0	0	0	3
MS	MAN	LCT: Solid Wastes Manag.	0	1	0	0	TIRE DEALER NET	Enterprise	None	1	1	0	0	0	0	2
MS	ENGEL	LCA, LCM: Electronic Wast Manag.	0	1	1	2	CEFET-RJ EDU ORG BR	University	Student	1	1	0	0	0	0	2
MS	ENGMEC	LCT: ORG STUD, Tire Production	0	1	1	2	TIRE IND	Enterprise	Employee	1	1	0	0	0	0	2
MS	ENGPRO	LCA, LCM: Animal for Experiment	0	1	0	0	HEALTH RESEARCH P. ORG.	Research inst	Employee	1	1	0	0	0	0	2
MS	MAN	LCT: 21 Agenda. Social Net B.P.	0	1	1	0	EDU ORG 2	Institute	Covenant	1	1	0	0	0	0	2
SI	ENGST	LCA: Plastic Wood Production	0	1	1	NA	PLASTICWOOD IND	Enterprise	Covenant	1	1	0	0	0	0	2
SI	ENGST	LCA: Plastic Wood Production	0	1	1	NA	PLASTICWOOD IND	Enterprise	Covenant	1	1	NA	NA	NA	NA	2
SI	ENGST	LCA: Plastic Wood Production	0	1	1	NA	PLASTICWOOD IND	Enterprise	Covenant	1	1	0	0	0	0	2
SI	MANST	LCA: Tire Reverse Logistic	0	1	1	NA	PLASTIC IND	Enterprise	Covenant	1	1	0	0	0	0	2
FP	ENGST	LCT: ORG STUD, Off. Ind. Funding	0	1	1	1	PUBLIC ENTERP 2	Enterprise	Employee	1	NA	NA	NA	NA	NA	1
MS	ENGPRO	LCT: Solid Wastes Manag.	0	1	0	2	AUTO MAINT	Enterprise	None	1	0	0	0	0	0	1
SI	ENGST	LCA: Plastic Wood Production	0	1	1	NA	PLASTICWOOD IND	Enterprise	Covenant	1	NA	NA	NA	NA	NA	1

SI scientific initiation (undergraduate student), MS master student, DS doctorate student, FP final project (undergraduate student), ECON economy, ENGCH chemical engineering, ENGMEC mechanical engineering, ENGEL electrical engineering, ENGEL electrical engineering, ENGPRO production engineering, IT information technology, MAN management, NUTRI nutrition, PHAR pharmacy, B.P. blind people, PPE previous professional expertise, CAP change in professional attitude, CAOP change in academic or organizational profile, CPT change in professional trajectory, MDLF motivated discussion local focus, MDAF motivated discussion amplified focus, MSD motivated strategic discussion, MMC motivated management change, MPC motivated planning change, MSC motivated strategic change, MOC motivated organization change, NA not applicable

3.3 Indicators of change

In agreement with Baumann (2000), to understand what is happening with (LCA) projects in companies, it is necessary to listen to what people say. This qualitative approach, as in the strategies related to the Grounded Theory (Glaser and Strauss 1967), is essentially empirical and makes it possible to observe facts and find out patterns from similarities and differences between the cases studied. Accordingly, a set of indicators was created to map both dimensions of perceptions: what the human actors could say about themselves and what they thought about the relations, supposedly motivated by them, with other actors inside the productive organizations under study. As mentioned before, they were built with three sources of information, including interviews that consisted of conversations between students, staff of organizations, and professors while carrying out their researches interspersed with observations of data and facts occurring in organizations and in-depth discussions. The key questions and the numerical values used in these interviews are detailed in Table 2.

3.3.1 Analysis of change

Table 3 listed data of 25 individuals and 21 organizations from the greatest to the smallest value of the MOC indicator. The timeline was neglected in this process, and the common legend for previous figures was repeated for more clarity.

Individual changes can be related to indicators presented from columns 3 to 7. The first one, PPE, is zero for all actors. It indicates that there was no previous professional expertise in topics related to sustainability. It also points out the lack of theoretical knowledge about these matters in the curricula of several undergraduate courses, which reinforces the importance of LCT. In the case of CEFET/RJ engineering students, it is highlighted that they only had this type of information near the middle of the course.

The next indicator, CPA, equals 1 for all actors and indicates changes in concepts and operational routines in their professional lives once they have had contact with academic information about LCT, LCM, and LCA. This is a strictly personal point of view, and there is no need that these individual changes have coincided with equivalent changes in the organizations, where these actors were researching or working. The comparison with PPE shows that the strategy adopted, based in LCT, was effective to mitigate the lack of previous academic education about sustainability themes.

For seven actors, CAOP indicator equals zero. Then, for almost one third of the individuals, the personal changes declared did not affect their academic or professional profiles. For the remaining 18 actors, changes occurred. When this number is confronted with CPP, it can be observed that only four of these actors remained in the same job and only two of them were in the group of organizations that reached strategic

changes (MOC=6.0). There were four actors that had to find jobs elsewhere. Among the organizations with deeper changes, these two situations appear three times each. There is no clear pattern associated to origin, research topic, or other attribute of the individuals.

There is, instead, a strong influence of the companies' conditions in this indicator. The PHARM INDUSTRY 3, e.g., seems to be promising for pharmacists to stay and implement deep changes. In fact, in this case, the senior management had progressively embraced the large use of LCM and LCA. The two other MS students and pharmacists had to find new places to advance professionally. Students and researchers found good opportunities in ECOWOOD, which was expected because of the partnership with FAPERJ and CEFET/RJ.

In general, the students assimilated the systemic representations and crossing fluxes of matter and energy used in LCA, fairly well, regardless of the undergraduate course they came from. The main difficulties started when it was necessary to apply the models to the real processes. On the one hand, there is much to be done in Brazil about national inventory data because only recently (MDIC 2010) has the legal basis for such documentation been established. This means that there is almost no local data available. On the other hand, the models for calculation of environmental impacts in commercial software were not conceived for the local reality.

To overcome this problem and taking in consideration that most of the researches were in their initial stages, the LCA's scopes were limited to door-to-door scenarios. Even though, there was still a serious problem to accomplish the inventory, as the contacted local managers were not familiarized with data measurement and control required to run LCA. In other cases, the available figures were not metrologically reliable.

In some models, the data from ECOINVENTTM were employed, not without pondering clearly their local validity. These facts were found in all the organizations observed and determined limitations to the ongoing LCA. In many cases, considering the limited time of the students to conclude their researches, it was not feasible to gather enough data that allowed going further than the inventory of mass and energy. On the other hand, these limitations did not disturb the interest or the mobilization for changes in some organizations since they had started. In many situations, the initial mass and energy analyses inside the companies were already powerful enough to convince the people that things ought to be changed and caused deep impression about the even more interesting potentials of more complete and comprehensive LCAs. The economical rationality still prevailed whenever the values of inputs consumed in the processes have been clearly detailed, but the perspective of sustainability was also discussed and eventually started to be considered. In a few cases, it motivated the organization to rethink some of its relationships with suppliers. In others, it motivated the training of professionals in LCA.

When the organizations were observed, the first indicator, MDLF, was positive for all cases and this was almost equivalent to the case of CPA for human actors because it demonstrated the general interest to discuss sustainability themes inside organizations. What should be the boundaries of this discussion? The next indicator, MDAF, was equal to 1 in all cases and surprisingly answered the question asked: There were no barriers for communication in any of the organizations observed. The relevance of this communication process, as one can admit, depends on the size, culture, and other peculiarities of the social context that should be investigated, mainly around the kind and extension of the consequences produced in every case, but this is beyond the scope of this work.

However, when the discussions went further, encompassing several areas, the planning of the organization was affected and higher hierarchical levels were involved. This was pointed out whenever MMC indicator was equal to 1. This revealed a pattern for organizations that have changed motivated by the use of LCT. This pattern was associated to the MOC indicator assuming values between 4 and 6, which included 10 organizations. Among them, four private and three public organizations reached the maximum value. In this set, three pharmacists

and one nutritionist, health professional, and non-employee of the organizations were in charge of disseminating LCT, LCM, and LCA through covenants with CEFET/RJ. On the other side, an economist, employee, graduate student did the same in a food sector company.

In Fig. 3, it is possible to compare results from individuals and organizations. When the MOC is compared with CPT and CAOP, it is clear (superior right quarter) that whenever deep changes have happened in any organization (MOC=6.0), the conceptions and/or attitudes of the individual linked to it have also changed (CAOP=1.0). The converse is not necessarily true because the individual could have changed his mind without any influence from the organization associated to him, as it did not have any relevant change (inferior left quarter). There were job changes in both situations (CPT=2): when the organization experienced deep changes (4 points at superior right quarter) or when the modifications were limited to comprehensive discussions (5 points dispersed around the three other quarters), but there are three cases in which CPT is equal to 1 and MOC is equal to 6. This means that the professional changed his position *inside the company* that achieved deep changes.

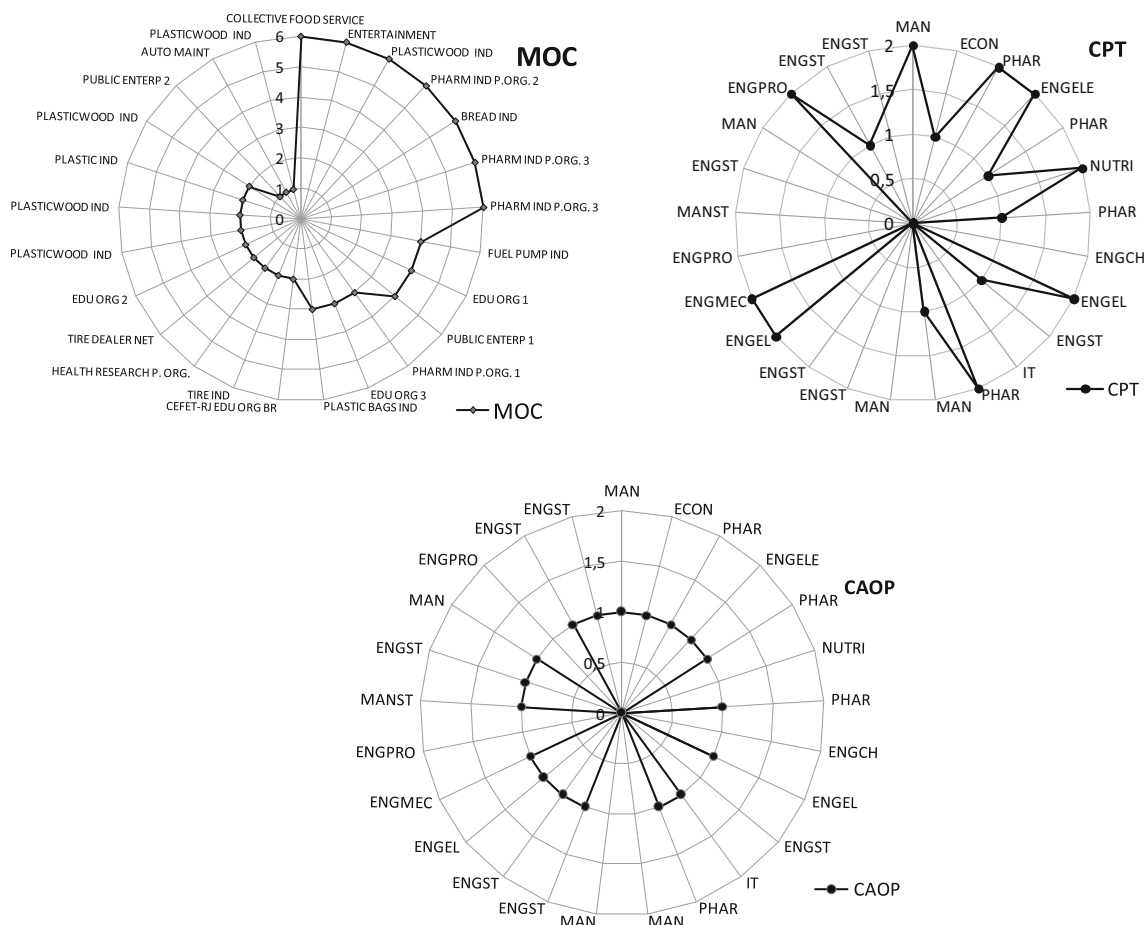


Fig. 3 Distribution of indicators *MOC* motivated organization change, *CPT* change in professional trajectory, *CAOP* change in academic or organizational profile

In all cases, one can admit that permeability to LCT, LCM, and LCA indicates the first steps of a potential process of innovation. When this permeability reaches higher levels of decision, greater changes are ready to happen, but it could take some time until they reach the point to generate any concrete alteration in the production processes. It is beyond the scope of this article to detail the changes in each organization observed as they are completely different in many aspects; each one must be analyzed within their particularities. Nevertheless, some remarkable events can be summarized: deep changes in marketing strategies at a great industry, incorporation of sustainability as a critical value, hiring of professionals to apply LCA and LCM in production process at a public institution, and changing of guidelines for waste management using LCA at two organizations are among others. The changes affecting the other actors, as professors and undergraduate students, demand more time and space to be discussed, as well as the rich particularities of many promising cases of people and organizations, which were omitted because of these limitations.

4 Conclusions

The study has proved that the contact with LCT, LCM, and LCA contributed to give materiality to sustainability topics and, somehow, made up the minds of participative actors to start new reflections concerning their views about the organizational dynamics and about the necessity of changes in their professional profiles, mainly when acting in a collaborative work environment. This reinforces the premise that education can contribute considerably for any initiative oriented to sustainability.

The particular arrangement of networking experiences proved to be locally effective to engender and stimulate relations among actors interested in knowledge production, technology integration, and creativity oriented to sustainability. This arrangement is still alive and remains in continuous expansion. The authors understand that it may serve as a reference to similar initiatives and have kept it open to receive new collaborations.

The interactions with organizations allow observing the emergence of changes in diverse levels related to the contact of local culture with LCT. Particularly, the cases involving LCA application demonstrated that some challenges ought to be faced so that LCT, LCM, and LCA themes can evolve in Brazil: (1) the need to accelerate the national inventory, which was subject of a recently defined policy, but has not yet satisfied current demands of productive organizations; (2) the need of academic knowledge and of greater engagement of scholars in order to support the professional's education aligned with LCT and to contribute with the development of national and local methodologies demanded by the comprehensive application of LCA and LCM; (3) the need to assist

many individuals at the organizations with theoretical and operational resources, which are already prepared for these themes, connecting them productively with other social actors; and (4) the problem of developing and supporting effective and enduring local and national networks to energize the several kinds of collaborative works needed to validate LCM and LCA models and to integrate the three former tasks.

Some of the issues mentioned suggest an important potential to produce improvements and innovations, involving government, productive sector, and academic organizations for which further detailed studies are needed.

Finally, this paper can inspire other readers of JLCA to integrate and improve the educational experience related or to experience similar approaches, with the support of LCT, which will strengthen UNEP/SETAC Life Cycle Initiative.

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